Appendix E
Location Hydraulics Study

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Subject: **11400 South EIS – Location Hydraulic Study**

The purpose of this report is to present the results of the Location Hydraulic Study (Study) as outlined in 23 CFR 650, Subpart A - *Location and Hydraulic Design of Encroachments on Flood Plains* for the 11400 South Environmental Impact Statement (EIS) for the selected project alternatives. The location hydraulic study performed for the 11400 South EIS focuses on the hydraulic impacts caused by project alternatives 1, 3A, 4, and 7.

The intent of the Study was to identify areas within existing natural stream channels that are being encroached upon or modified by the proposed improvements associated with the selected project alternatives. The floodplain analysis summarizes the impacts to floodplains at locations where the proposed roadway modifications encroach or impact an identified waterway.

A floodplain encroachment analysis was performed for the proposed 11400 South Street Jordan River crossing and for the proposed widening activities at 10600 South Street and 12600 South Street over the Jordan River. Impacts to Willow Creek (West) and Midas Creek crossings were investigated, however no hydraulic modeling was performed. Additionally, the hydraulics associated with irrigation canals were examined. Their quantity and tendency for intercepting and conveying storm related runoff within the Study warranted investigation. Minor and local drainages were not investigated as part of the Study.

The primary focus of this study was the hydraulic analysis of bridge configuration options associated with the proposed 11400 South Street bridge over the Jordan River. Drainage structures conveying Willow Creek (West) and Midas Creek have not been sized as part of this study. All structures will need to be sized during the design phase of the project in accordance with Utah Department of Transportation (UDOT), Federal Emergency Management Agency (FEMA), and local criteria pertaining to floodplain and conveyance designs. Additionally, the Preferred Alternative final design would need to meet the requirements established in 23 CFR 650, Subpart A for all structures impacting existing natural stream channels.

The results contained in this Study are for planning purposes only. A more comprehensive sizing and impact analysis is required for preliminary and final designs.

Site Location

The project study area is located in Salt Lake County, Utah, and includes the municipalities of South Jordan, Sandy, Riverton, and Draper. The Study is bounded on the east by approximately 700 East Street, on the west by approximately Bangerter Highway (UT HWY 154), on the north by approximately 10400 South Street (South Jordan Parkway), and on the south by approximately 12600 South Street. A more detailed project description and a project alternatives map can be found in the EIS.

Impacted Waterways

The project alternatives have the potential for impacting several existing waterways, irrigation canals, and drainage basins. Although final design efforts should attempt to minimize the impacts to waterways caused by the project, some permanent impacts should be expected.

FEMA has established regulatory floodplains, floodways, and base flood elevations (BFE's) for Willow Creek (West), Midas Creek, and the Jordan River, all of which would be impacted by the project alternatives to differing extents.

Although irrigation canals are not intended for conveying storm runoff, they often do intercept and convey drainage related flows. The identified project alternatives potentially impact Utah Lake Distribution Canal, Utah and Salt Lake Canal, South Jordan Canal, Galena Canal, and the Jordan and Salt Lake Canal.

Several other minor drainage corridors associated with local drainages and storm drain systems would also be impacted by the project alternatives. Structure upsizing and/or reconfiguration could be required for maintaining or improving the functionality of these drainage systems.

Flood History

Flooding has occurred on the Jordan River and it's tributaries throughout Salt Lake County's history. The most dramatic flood events have been the result of snowmelt and cloudburst thunderstorms. Flooding on the Jordan River has been heavily documented and analyzed because of the stream gages that exist along its length. However, very little information is available about flooding on Willow Creek (West) and Midas Creek.

Records indicate that the Jordan River has experienced flooding for recurrence intervals as high as the 250-year flood event (1862 Flood). More recent flooding on the Jordan River within the Study area has occurred in 1983 (42-year flood event), 1984 (100-year flood event), and 1986 (75-year flood event). No flooding dates or recurrence intervals are available for floods associated with Willow Creek (West) and Midas Creek.

Some of the Jordan River's flood events have corresponded with high stage elevations on Lake Utah. Snowmelt runoff during the months of April, May and June for years where the annual snow accumulation was excessive induced above average lake levels. Prior to 1985 and 1987, when improvements where made to Lake Utah's outlet structure, high lake levels on Lake Utah caused flooding on the Jordan River.

Releases from Lake Utah are heavily regulated based on legal agreements and the demand for irrigation water. Diversion of irrigation water from the Jordan River has been shown to reduce the flood flows in the River, and aid in reducing flood related damage. The ability of an irrigation diversion structure to reduce peak flows should be considered as circumstantial. An irrigation diversion structure should not be considered as a flood control feature. Their reliability is questionable and inconsistent. However, their existence impacts the extent to which flooding and flood related damage occurs on the Jordan River.

Historically, damage caused by flooding on the Jordan River has resulted in the failure of various irrigation structures and resulted in bank erosion and channel migration. Lateral migration of 300 to 400 feet has been documented after flooding events. No documentation was obtained that stated that flooding on the Jordan River resulted in loss of life or buildings.

Alternatives

The following section discusses the floodplain impacts associated with the various project alternatives discusses within the EIS. The discussion focuses on increases to flooding elevations and floodplain encroachment resulting from the proposed alternatives. Detailed discussion of the alternatives can be found in the EIS.

No Action Alternative

This alternative produces no change to the floodplain.

Alternative 1

This alternative would result in floodplain encroachments at:

- Three locations on the Jordan River (10600 South Street, 11400 South Street, and at 12600 South Street).
- Two locations on Willow Creek (West) (11400 South Street and 12600 South Street).
- One location on Midas Creek (11400 South Street).

Encroachments associated with 10600 South Street and 12600 South Street would occur as a result of widening the existing roadway. Encroachments associated with 11400 South Street would be the result of the new roadway crossing and improvements to the existing sections of 11400 South Street. Extents of encroachment will be dependent on the final roadway configuration and design.

This alternative includes a new Jordan River crossing (11400 South Street) that results in increased flooding elevations upstream of the proposed bridge (see Hydraulic Analysis section of this Study for estimated increases). Widening of the existing bridges over the Jordan River (10600 South Street and 12600 South Street) would have negligible impact on upstream flooding elevations. The existing structures already confine or "pinch" the floodplain, increasing the confinement length by several feet will not significantly alter the bridge hydraulics and associated backwater effects.

This alternative could impact several irrigation canals. The proposed alternative cannot have any adverse impact on the functionality or water quality of the canal. Coordination with the irrigation company or canal owner is warranted.

Alternative 3A

This alternative would result in floodplain encroachments at:

- Two locations on the Jordan River (10600 South Street and at 12600 South Street).
- One location on Willow Creek (West) (12600 South Street).

Encroachments associated with 10600 South Street and 12600 South Street would occur as a result of widening the existing roadway. Extents of encroachment will be dependent on the final roadway configuration and design.

Widening of the existing bridges over the Jordan River (10600 South Street and 12600 South Street) would have negligible impact on upstream flooding elevations. The existing structures already confine or

"pinch" the floodplain, increasing the confinement length by several feet will not significantly alter the bridge hydraulics and associated backwater effects.

This alternative could impact several irrigation canals. The proposed alternative cannot have any adverse impact on the functionality or water quality of the canal. Coordination with the irrigation company or canal owner is warranted.

Alternative 4

This alternative would result in floodplain encroachments at:

- Two locations on the Jordan River (11400 South Street and at 10600 South Street).
- One location on Willow Creek (West) (11400 South Street).
- One location on Midas Creek (11400 South Street).

Encroachments associated with 10600 South Street would occur as a result of widening the existing roadway. Encroachments associated with 11400 South Street would be the result of the new roadway crossing and improvements to the existing sections of 11400 South Street. Extents of encroachment will be dependent on the final roadway configuration and design.

This alternative includes a new Jordan River crossing (11400 South Street) that results in increased flooding elevations upstream of the proposed bridge (see Hydraulic Analysis section of this Study for estimated increases). Widening of the existing bridge over the Jordan River (10600 South Street) would have negligible impact on upstream flooding elevations. The existing structure already confines or "pinches" the floodplain, increasing the confinement length by several feet will not significantly alter the bridge hydraulics and associated backwater effects. Final design and analysis will verify this assumption and mitigate for any associated impacts.

This alternative could impact several irrigation canals. The proposed alternative cannot have any adverse impact on the functionality or water quality of the canal. Coordination with the irrigation company or canal owner is warranted.

Alternative 7

Alternative 7 has the same floodplain impacts as Alternative 4.

Drainage Structure Sizing

During the final design, all drainage structures associated with the Preferred Alternative will be sized to meet the requirements of 23 CFR, UDOT Drainage Design Criteria, as well as any other applicable local, state, or federal drainage design requirements. Bridges and box culverts shall not cause more than a one-foot rise in upstream water surface elevation for the 100-year flood event. Furthermore, final structure sizing shall be cognoscente of:

- Potential downstream impacts associated with increasing an existing structure size.
- Potential for erosion or waterway instability.
- Impacts associated with debris accumulation.
- Impacts and structure functionality during flood events greater than that used for the structure's design event.

Preliminary structure sizing performed for the Study assumed bridges with low chord elevations two-feet above the 50-year flood event, and no low chord inundation during the 100-year flood event. Impacts associated with the 500-year flood event were not investigated. Box culverts conveying Willow Creek (West) and Midas Creek were assumed to be replaced with structures larger than those that currently reside at the crossing locations.

Floodplain Analysis

A concept level floodplain analysis was conducted to meet the requirements of 23 CFR 650, Subpart A. This section of the Study summarizes the analysis approach and results for each of the investigated alternatives. As previously mentioned, the floodplain investigation focused on the proposed 11400 South crossing of the Jordan River. Floodplain impacts associated with possible modifications to the existing 10600 South and 12600 South crossings of the Jordan River have been determined to be negligible. Floodplain impacts associated with possible modifications to Willow Creek (West) and Midas Creek are considered to be negligible due to the assumption that the existing structures will either be extended in kind or replaced with larger structures that result in less floodplain impacts.

The Jordan River, Willow Creek (West), and Midas Creek all have floodplains with areas identified as Zone AE (*Base Flood Elevations Determined*) in the FEMA Flood Insurance Rate Maps (FIRM's). Both Base Flood Elevations (BFE's) and Floodways have been determined for all three of these waterways. Since regulatory floodplains have been identified by FEMA, they will be evaluated to meet the requirements of the National Flood Insurance Program (NFIP) as identified in 23 CFR 650 and as regulated by 44 CFR.

Hydrology

The 1%, 2%, and 10% chance flood events (100-year, 50-year, and 10-year flood events) flow rates for the Jordan River, Willow Creek (West), and Midas Creek were obtained from the Salt Lake County Flood Insurance Study (FIS). Table A lists the flow rates for these waterways:

Table A Study Flow Rates

Flood Event	Jordan River [A]	Willow Creek (West) [B]	Midas Creek [C]
10-year	1,260 cfs	200 cfs	372 cfs
50-year	2,400 cfs	350 cfs	907 cfs
100-year	3,000 cfs	380 cfs	1,139 cfs

Source: *Salt Lake County Flood Insurance Study*.
Note:

- **A**, Jordan River flow rates apply for 10600 South Street, 11400 South Street, and 12600 South Street Crossings.
- **B**, Willow Creek (West) flow rates at 11400 South Street. Flow rate is not valid for analysis of crossing at 12300 South Street.
- **C**, Midas Creek flow rate is valid for 11400 South Street analysis.

Hydraulic Analysis

Hydraulic analysis focused on the Jordan River, specifically crossing options associated with the proposed 11400 South Street Crossing, Alternatives 1, 4, and 7. Hydraulic impacts associated with widening the existing 10600 South Street and 12600 South Street structures crossing the Jordan River have also been analyzed. Structures conveying Willow Creek (West) and Midas Creek are anticipated to

be replaced with larger culverts, or extended in kind. Either way, no adverse floodplain or conveyance impacts are anticipated by the project alternatives.

Bridge configuration modeling and estimation of associated floodplain impacts were determined with HEC-RAS. The regulatory FIS HEC-2 hydraulic model was obtained from FEMA and converted to HEC-RAS. The model was modified with cross sections in the 11400 South Street crossing vicinity, and different bridge configurations were analyzed. The model was also updated to reflect the existing conditions for the existing 10600 South Street and 12600 South Street structures. The bridge configurations contained within the regulatory model did not reflect the existing conditions for either of these crossings.

10600 South Street and 12600 South Street Hydraulic Analyses

Hydraulic impacts associated with widening the existing 10600 South Street and 12600 South Street structures crossing the Jordan River were analyzed. Widening plans, for all alternatives requiring widening activities, necessitate the widening of 10600 South Street by approximately twelve feet, and 12600 South Street by less than ten feet. Additional lane accommodation is largely based on providing smaller shoulder, median, and sidewalk widths.

The widened structures will induce hydraulic conditions during flooding events that are similar to those exhibited by the existing structures. The widened structures caused backwater increases for the 100-year flood event less than 0.25 inches. Even though the proposed widening activities have virtually no impact on flood flow elevations, the final widening designs will require hydraulic analysis.

11400 South Street Hydraulic Analysis

Four different 11400 South Street bridge configurations, associated with Alternatives 1, 4, and 7, have been analyzed. Their configurations and associated backwater impacts on the floodplain are included in Table B.

Table B Hydraulic Analysis Results

Option	Bridge Configuration	Estimated 100-Year Flood Increase to FIS	Estimated 100-Year Flood Water Surface Elevation
A	Three Span (73', 191', 73'), Skew = 30º	0.57 feet	4322.0
B	Three Span (82', 245', 82'), Skew = 8º	0.47 feet	4321.8
C	Three Span (82', 154', 82'), Skew = 8º	0.51 feet	4322.0
D	Three Span (102', 204', 102'), Skew = 20º	0.47 feet	4321.9

Note:

- Only results associated with the FIS 100-year flood event are being presented.
- Estimated 100-year Flood Water Surface Elevations are at the upstream bridge cross section and reference NGVD 29 (FIS Datum).
- Q_{100} increase to the FIS is based on FIS Cross Section GN1. FIS Cross Section GM has been removed from the model due to its location within the proposed bridge's flow contraction zone.
- All options assume that the bridge configuration includes an attached pedestrian walkway.

The estimated 100-year flood event increases to the FIS are based on published regulatory water surface elevations at FIS Cross Section GN1. (see figure A)

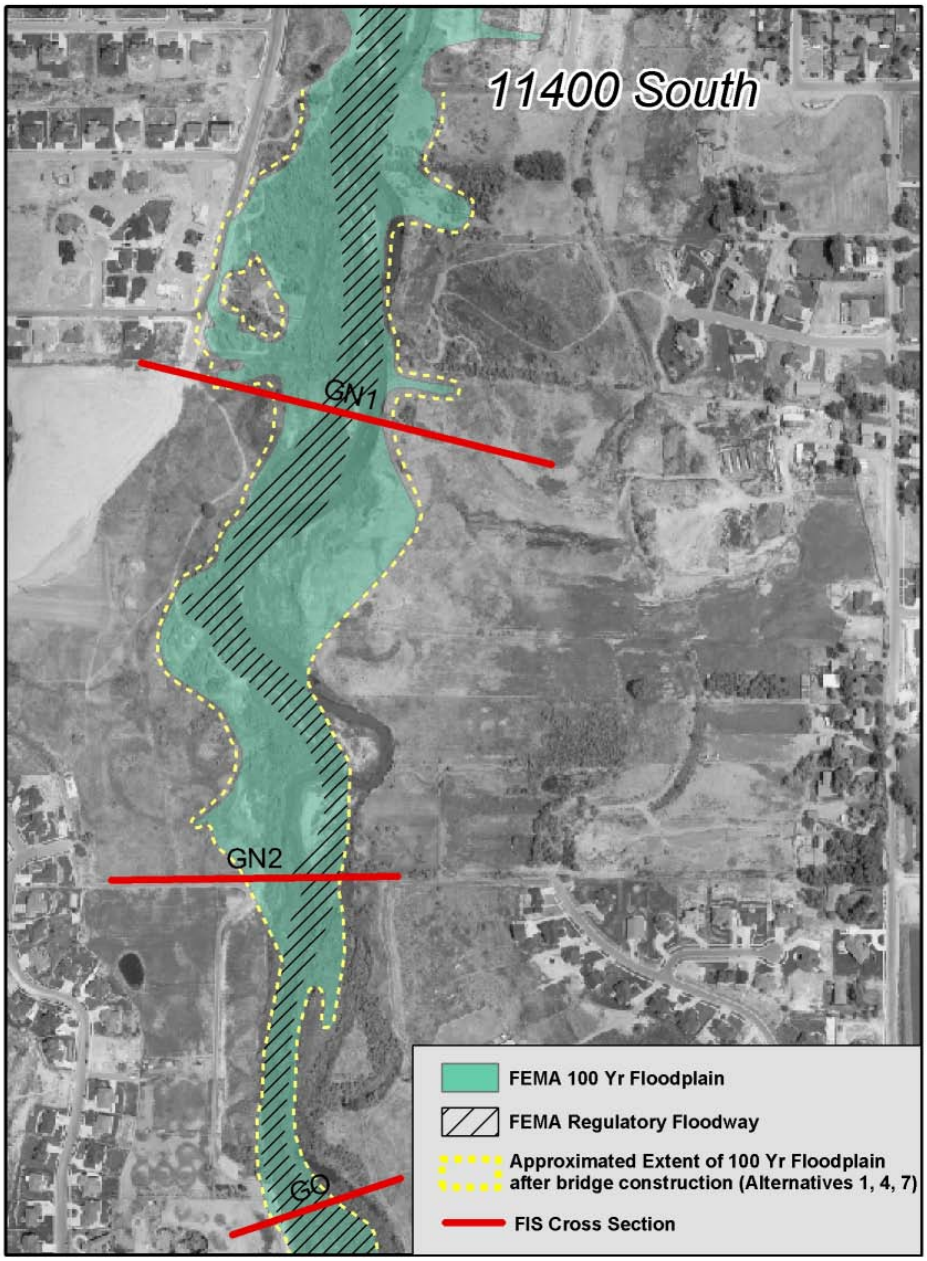

Figure A. Approximate changes in 100 yr floodplain extent due to bridge construction

FIS Cross Section GM is actually closer to the proposed 11400 South Street crossing; however it was removed from the hydraulic model due to its location within the proposed bridge flow contraction zone. Final bridge sizing impacts will need to be compared with a revised regulatory model that includes the 11400 South Street vicinity cross sections and has been updated to reflect the existing floodplain conditions upstream of the proposed bridge crossing. Revision of the regulatory model may reduce the estimated floodplain impacts associated with the proposed structure.

Option A

Option A, was the first bridge opening configuration considered. It consisted of a three span 337-foot bridge that would span straight across the river. The bridge included space for a pedestrian/equestrian trail along both of the spill through abutments. The bridge piers were placed adjacent to the active channel corridor. A wildlife buffer of approximately fifteen feet was left between the edge of the channel and the bridge piers. Because of the river's low flow channel meander at this location, the bridge piers and abutments were skewed at approximately 30º to the river's floodplain alignment.

This bridge configuration could create excessive bridge scour, warrant deeper bridge foundations, and result in increased flood elevations immediately upstream of the proposed crossing.

Option B

Option B, included skewing the proposed bridge opening to approximately 8º and lengthening the bridge to 409 feet to maintain the spanning of the active channel corridor. The bridge included space for a pedestrian/equestrian trail along both of the spill through abutments. The bridge piers were placed adjacent to the active channel corridor. A wildlife buffer of approximately fifteen feet was left between the edge of the channel and the bridge piers. This bridge configuration was ideal for meeting the bridge opening requirements and resulted in minimal backwater increases. However, it is difficult for this bridge configuration to tie into River Park Drive, which is an essential requirement for any 11400 South Street crossing alternative.

Option C

Option C**,** was a bridge configuration that evolved from trying to establish an ideal roadway tie-in at River Park Drive. Essentially, all of the ideal intersection characteristics and pedestrian/equestrian trail layout were incorporated into the roadway configuration. A bridge opening location was then established from the ensuing configuration. This bridge opening location does not line up with the Jordan River's existing low flow channel. Minor channel realignment would be required. Option C would need to include moving the Jordan River in the vicinity of 11400 South Street into an older channel location, which currently conveys flows during high water events. The proposed three span bridge would span the newly created active channel corridor at approximately 8º and have a total length of 318 feet. The bridge included space for a pedestrian/equestrian trail along both of the spill through abutments. The bridge piers were placed adjacent to the active channel corridor. A wildlife buffer of approximately fifteen feet was left between the edge of the channel and the bridge piers.

This option would necessitate the installation of a boatable drop structure, low flow channel armoring, and overbank grading to maintain the stream alignment and decrease the likelihood for lateral migration. All of these elements would need to be designed, analyzed, and approved by the regulatory agencies during the design phase of this project.

The advantages of this alternative include a reduced bridge length, reduced bridge costs, an ideal intersection configuration at River Park Drive, and the potential for wetland mitigation at the realigned meander. In addition, the drop structure would prevent the downward cutting of the river into the stream channel, which is reportedly occurring.

Option D

Option D was the result of an agency coordination meeting held in March 2004. In an effort to minimize structure depth and accommodate an adjacent pedestrian crossing, the proposed three span bridge

included a 20º skew and longer back span lengths. The bridge configuration spans the active channel corridor and includes ten feet of wildlife buffer along the channel sides of both piers. As with Option B, this bridge configuration option is ideal for meeting the bridge opening requirements and resulted in reduced backwater increases. However, this bridge configuration requires modification of River Park Drive in order to accommodate an 11400 South Street intersection.

In addition to the four options contained in Table B, a separated pedestrian bridge configuration was analyzed for Options A and B. For both of these options, resultant water surface elevations and estimated increases in floodplain inundation during the 100-year flood event were negligible when compared with their attached pedestrian bridge configurations.

All of the bridge configuration options investigated as part of the Study resulted in less than one feet of increase to the 100-year floodplain water surface elevation, which can be characterized as a minor impact. Regardless, FEMA coordination and permitting will be required since the bridge options encroach into the Jordan River's regulatory floodway. All options had bridge piers and abutments located within FEMA's regulatory floodway.

Flooding Risks

Increased flood elevations upstream of the proposed 11400 South Street crossing of the Jordan River could have an adverse impact on the properties located in the vicinity of the Chapel Ridge Drive and River Road intersection. This area is inundated during large flood events. The area to the west of the intersection is delineated by FEMA as Zone X, (*areas of 500-year flood; areas of 100-year flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 100-year flood*). Final bridge sizing will have to be cognoscente of increased flooding elevations at this location. More detailed analysis, and possibly a revision to the regulatory model, will be required. Any increases to flood elevations, or potential for additional flooding, at this location will need to be mitigated either through grading efforts, a levee system, or property acquisition.

Additional flooding risks associated with alterations to the Willow Creek (West) and Midas Creek crossings should be negligible. This study assumes that the structures conveying creek flows are being replaced with larger ones.

Floodplain Values

Generally, a wide floodplain provides opportunities for the deposition of sediment (carried during high-flow events) along and behind the existing stream banks. These deposits provide the ideal conditions for riparian woodland and wetland development. The development of these plant communities increases the wildlife habitat value of the area and generally leads to a more ecologically functional system. Additionally, floodplains provide additional conveyance capacity for flooding events, and attenuate flooding events by providing storage areas.

The Jordan River's wide uninhabited floodplain setting is wide enough for stream migration and the development of these more diverse and valuable habitats. Additionally, the river's setting allows for low flow channel migration. It is natural for stable rivers to meander and for riverbank locations to change in location and configuration over time. A natural channel is in a constant state of flux, trying to adjust to the impacts caused by high and low flow events.

The beneficial attributes associated with smaller floodplains are often overlooked because of their relative size. The Willow Creek (West) and Midas Creek floodplains also provide flood conveyance, flood attenuation, and wildlife habitat, however to a much lesser degree when compared to the Jordan River's

floodplain. From a flooding perspective, minor floodplains reduce the hydraulic, hydrologic, and erosion potential for downstream areas. The reduction or elimination of Willow Creek's (West) and/or Midas Creek's floodplains would have a profound adverse impact on the Jordan River and its floodplain.

The placement of fill within the floodplain for any of the roadway options would have a negative effect on floodplain values. The fill itself would reduce or eliminate existing natural beneficial floodplain areas. Additionally, in the case of the 11400 South Street alternatives, fill placement bisects the floodplain and not only inhibits flood flows, but also possible wildlife passage within the floodplain corridor.

Floodplain Development

The proposed project and its Preferred Alternative are necessitated by the growth and development occurring to the west of the Jordan River. Given the current trends for the Salt Lake County area, development will continue for many years to come. Much of this development will occur in areas that are currently open space and/or agricultural.

Salt Lake County's Meander Ordinance has not always prevented development in close proximity to the river. The Jordan River Floodplain within the project study area has experienced some fringe development, however very little construction, aside from transportation related projects, has actually occurred within the regulatory floodplain (Zoned AE by FEMA).

It is plausible to believe that this trend will continue and that Jordan River floodplain development within the project study area will be limited to floodplain and river improvements, trail projects, and habitat improvements. However, if this is not the case, all future site development will need to be individually evaluated to determine impacts to floodplains and to assure that FEMA and County floodplain requirements are being met.

Due to their size and proximity to developable land, the same assumptions cannot be made regarding Willow Creek (West) and Midas Creek. Some floodplain encroachment due to housing and commercial development should be anticipated. Regardless, all future site development will need to be individually evaluated to determine impacts to floodplains and to assure that FEMA and County floodplain requirements are being met.

Minimizing Impacts

Floodplain impacts may be minimized or eliminated during the project's design phase. As encroachments into the floodplains or natural channels are identified, the project design team will evaluate design options that meet project design requirements and reduce the project's impact on floodplains. FEMA and County coordination will be required and FEMA permitting may be required for addressing the final design's impacts.

Structure crossings will be sized to meet UDOT drainage criteria, FEMA requirements outlined in 44 CFR, and any additional requirements outlined in 23 CFR 650. A one-foot maximum rise in water surface elevation for the 1% chance flood is allowed by all of these requirements, however prudent design may dictate a lesser rise. In cases where these requirements cannot be met, a formalized CLOMR and LOMR will be required by FEMA.

Restoration and Preservation of Floodplain Values

Although some negative impacts to the floodplain values may result from the project, several measures can be implemented to restore, preserve, and enhance the floodplain values. These measures include the

use of retaining walls and steeper roadway embankment slopes, stream relocation and floodplain enhancements, and the inclusion of temporary and permanent Best Management Practices.

The retaining walls and steeper roadway side slopes would reduce the overall "footprint" of the roadway, whereby preserving as much of the natural floodplain as possible. The goal of the stream relocation and floodplain enhancements would be to increase the area of riparian and wetland vegetation, whereby restoring the floodplain values. These sorts of enhancements would occur in portions of the floodplain that are deemed suitable based on land availability and discussions with the interested agencies. Additionally, even if stream relocation is determined to be an undesirable alternative, low flow channel and wetland improvements can be incorporated into the project as part of the bridge opening grading efforts.

Sources

CH2M Hill, *Jordan River Stability Study*, Prepared for Salt Lake County, 1992.

CH2M Hill, *Utah Lake Jordan River Flood Management Program, Phase I Report*, Prepared for Salt Lake County, 1984.

Federal Emergency Management Agency, *Flood Insurance Study, Salt Lake County Utah and Incorporated Area,s* May 15, 2002.

National Audubon Society, *The Jordan River Natural Conservation Corridor Report*, Prepared for the Mitigation Commission and the U.S. Fish and Wildlife Service, September 2000.

U.S. Army Corps of Engineers, *Jordan River Ecosystem Restoration Plan Set*, Prepared by Tetra Tech, Plan Set Obtained March 2004.